U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3426
Sheet 2 of 2

Geostatistical Analytics

Geostatistical analytics of structural analysis, variogram modeling, cross validation, kriging, and estimation variance (Robertson, 2008) were used to identify spatial-autocorrelation structures of the MRVA bottom-altitude and thickness data. These analytics defined the geospatial framework for geostatistical estimation of MRVA bottom altitude and thickness as gridded interpolated surfaces on the 1-kilometer-resolution USGS National Hydrogeologic Grid (Clark and others, 2018) (figs. 1 and 3).

Structural analysis defined spatial-autocorrelation properties of the data that integrate differences between data values at each paired location and their separation distances into mathematical expressions of semivariance (of bottom altitude, figs. 4*A*, *B*) and log-semivariance (of thickness, fig. 4*C*), which form experimental variograms and variogram models (symbols and curves, respectively, fig. 4).

Cross validation was used to compare estimates of bottom altitude and thickness with actual data values (fig. 5). These estimates were determined by using averaging (kriging) weights developed for, and applied to, the data locations based on spatial-autocorrelation structures identified by the semivariance and variogram models. A result of cross validation indicated that filtering to remove 2,619 bottom-altitude values containing estimation errors larger than 25 feet would increase the range of spatial correlation by 70 percent, compared with the range of spatial correlation associated with the unfiltered data (compare range values on variograms for unfiltered and filtered data, fig. 4). Filtering was not applied to data from Hoffman (2017), because the spatial density of data values provided by this source defined local geohydrologic heterogeneity in the Mississippi Delta that was preserved in the geostatistical estimation process. The enhanced accuracy of the variogram model to estimate bottom altitude at the data locations is manifested in the nearly perfect regression ($r^2 = 0.999$) of variogram-model estimates with the filtered bottom-altitude data (based on 6,604 log picks), compared with the regression ($r^2 = 0.993$) of the corresponding variogram-model estimates with the unfiltered data.

Values of MRVA thickness were prepared for geostatistical estimation by subtracting bottom altitudes of the filtered data from DEM values at the data locations. Structural analysis, cross validation, and variogram modeling of thickness identified two outlier data points that were removed from the dataset. The resulting 6,602-element dataset was used to generate the thickness interpolation surface (fig. 3). The complexity of the spatial-autocorrelation structure of the thickness data, derived from the top and bottom surfaces of the MRVA, each defined by their own spatial-autocorrelation structures, resulted in a range of spatial autocorrelation for the thickness variogram model of about half of the range associated with the filtered bottom-altitude dataset (compare range values in figs. 4*B* and *C*). The spatial variability of the thickness data is manifested in the slightly lower agreement of the cross-validation regression of the variogram model with the thickness data ($r^2 = 0.926$, fig. 5*C*) compared with the agreement of the cross-validation regression of the corresponding variogram model with the filtered bottom-altitude data ($r^2 = 0.984$, fig. 5*B*).

Kriging based on the autocorrelation of data points and their distances established from structural analysis and variogram modeling was used to generate interpolated surfaces for the MRVA bottom altitude and thickness (figs. 1 and 3, respectively). The averaging weights established during variogram modeling form the basis of the kriging interpolation process that eliminates estimation bias caused by distance of the interpolation point from its neighbors, clustering, or shadowing of data.

Estimation-variance mapping of the interpolated bottom altitude and thickness shown in figures 6 and 7, respectively, indicates the spatial variation of uncertainty in the estimated surfaces. Regions containing comparatively large estimation variance indicate that additional bottom-altitude or thickness data obtained in these areas could reduce estimation variance and enhance the accuracy of the interpolated surfaces.

Bottom altitude

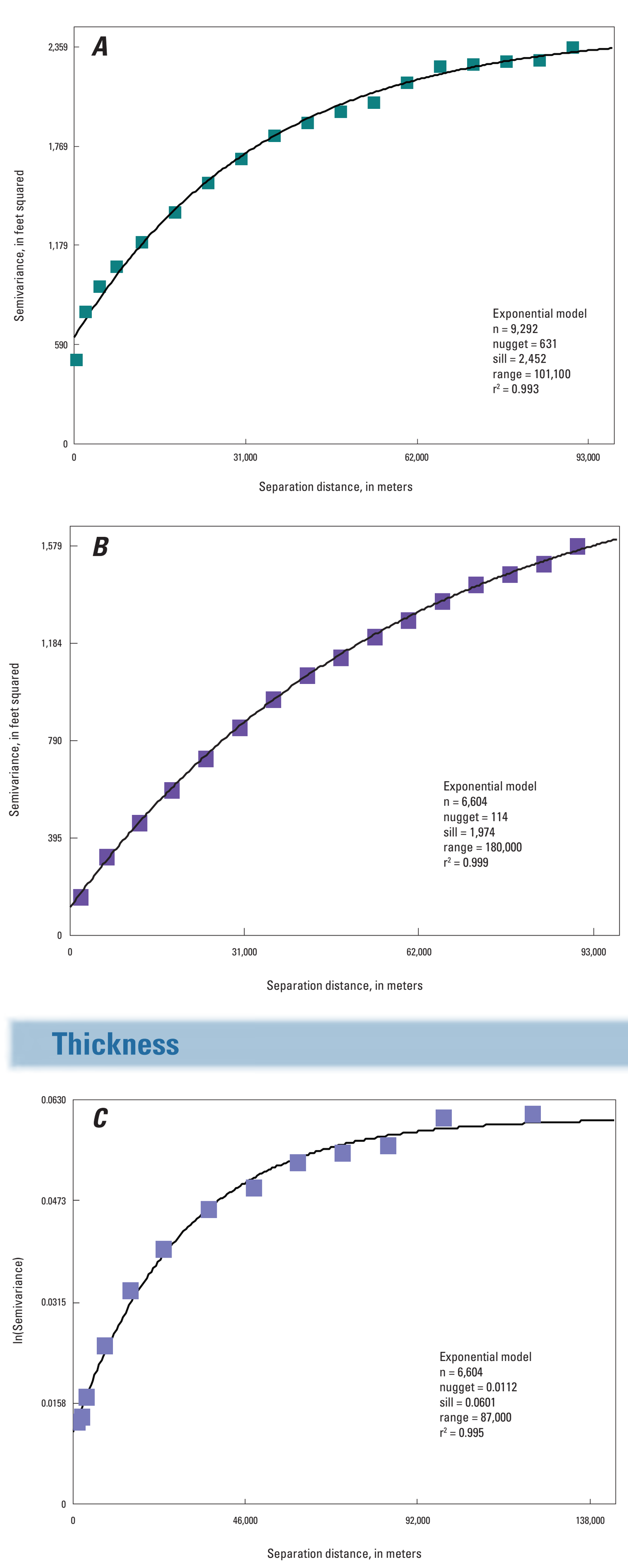

Figure 4. Isotropic variograms for Mississippi River Valley alluvial aquifer data showing semivariance of *A*, unfiltered bottom altitude and *B*, filtered bottom altitude and log-semivariance of *C*, thickness.

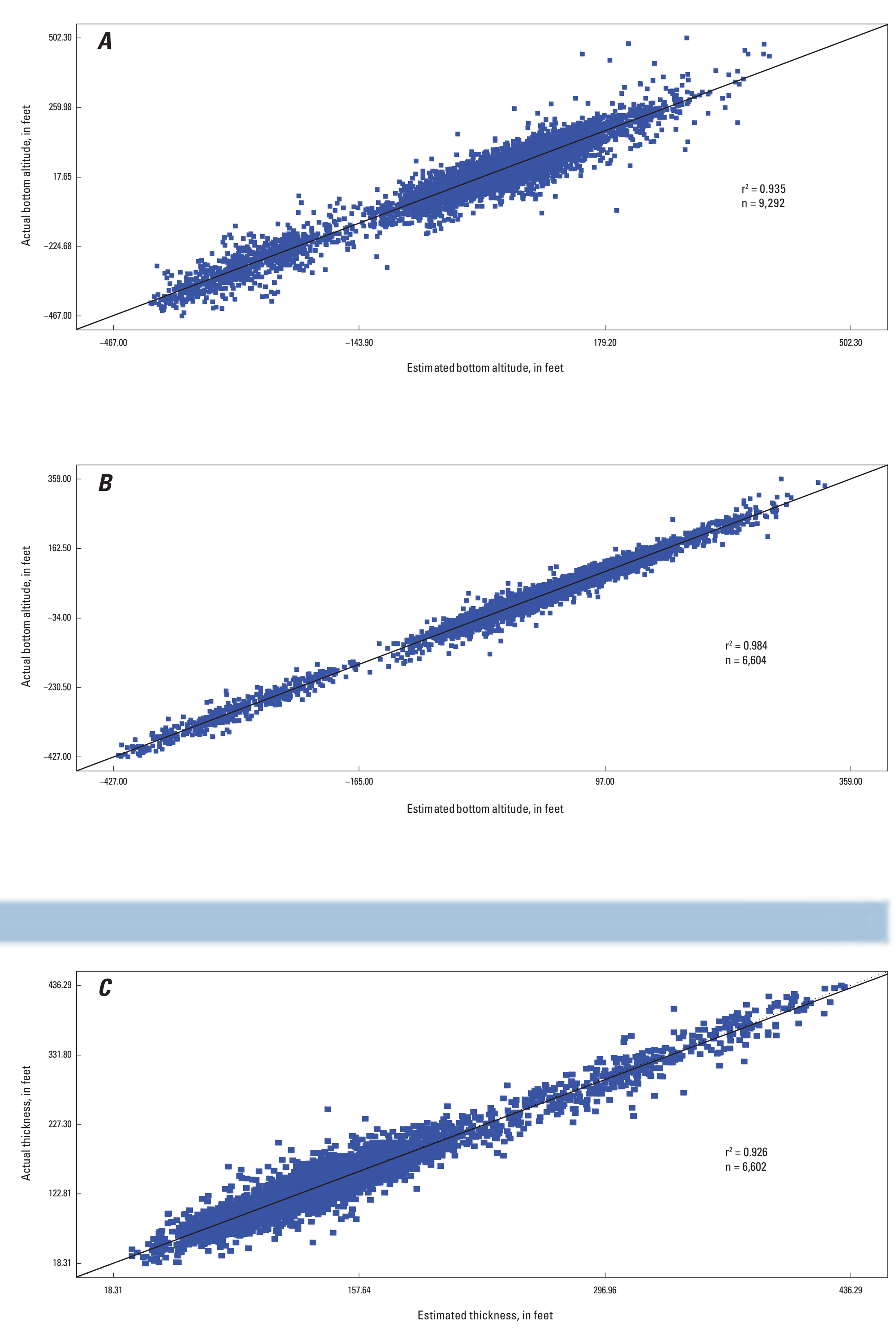

Figure 5. Cross-validation plots of actual and estimated values of Mississippi River Valley alluvial aquifer data for *A*, unfiltered bottom altitude, *B*, filtered bottom altitude, and *C*, thickness.

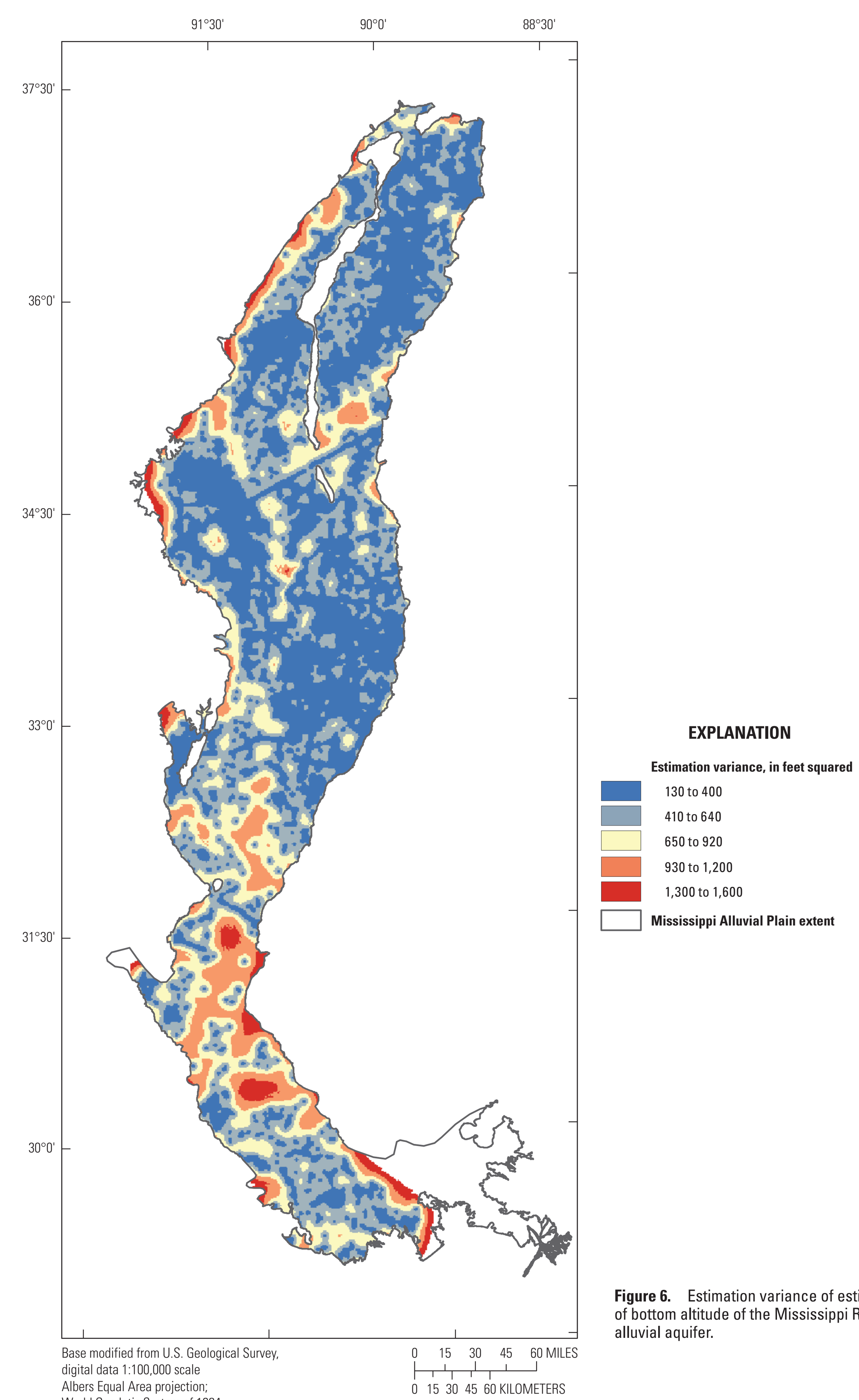

Figure 6. Estimation variance of estimated values of bottom altitude of the Mississippi River Valley alluvial aquifer.

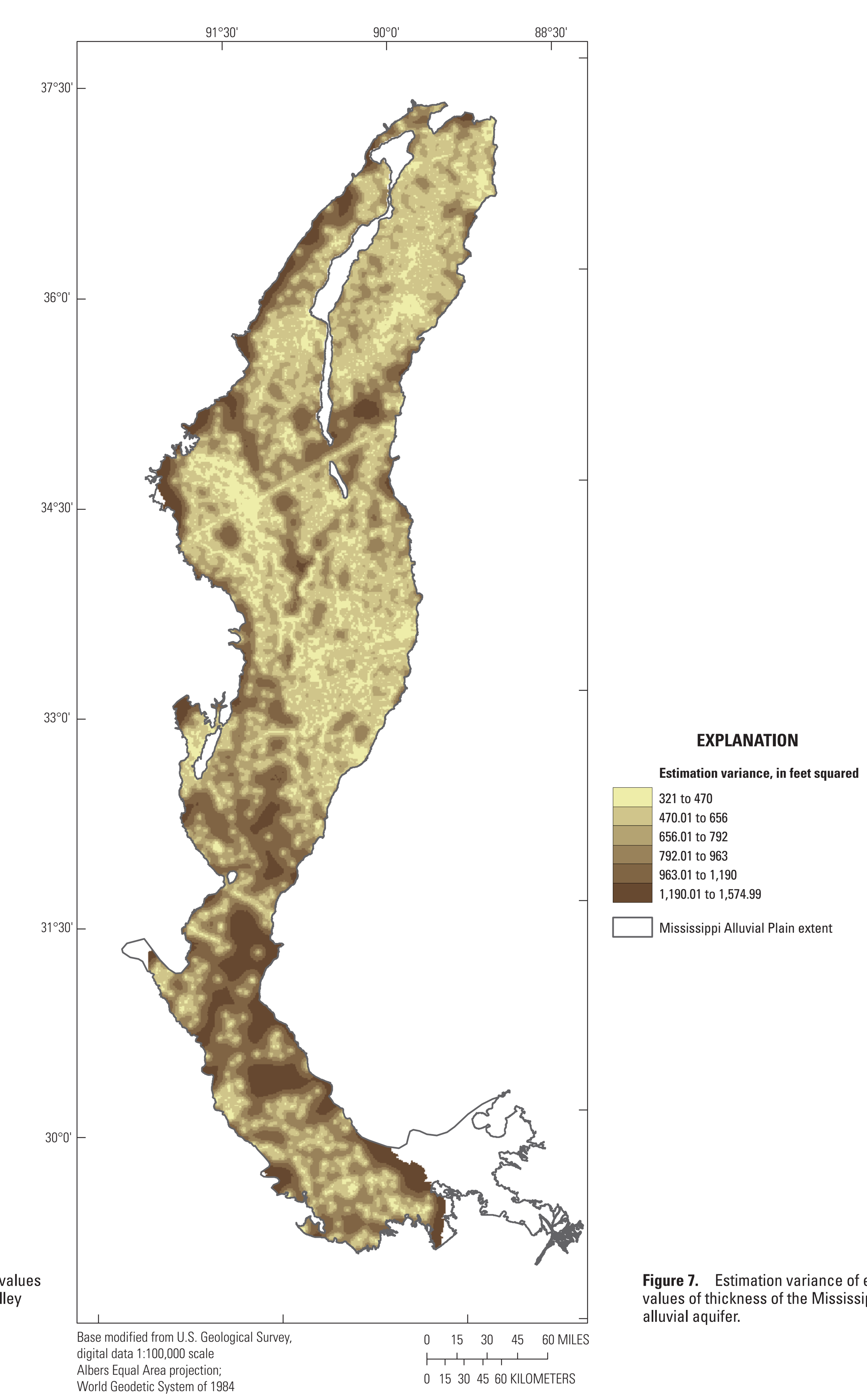

Figure 7. Estimation variance of estimated values of thickness of the Mississippi River Valley alluvial aquifer.

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